

PAST, PRESENT AND FUTURE OF FOOD- BORNE PARASITE RESEARCH

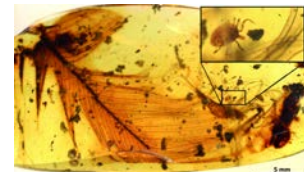
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The far past



- over millions of years, parasites have adapted to their hosts by escaping immune responses through different evolutionary choices:
 - development of the parasite in young hosts whose immune system is not yet well developed (e.g., *Cryptosporidium*, *Hymenolepis nana*)
 - development of the parasite faster than the host's immune response (e.g., *Toxoplasma*)
 - reduction of the exposure time to the final host's immune system due to developmental stages spent in intermediate hosts (e.g., *Fasciola*, *Opisthorchis*)
 - anatomical seizure of the parasite that does not come into contact with the host's immune system (e.g., *Echinococcus*, *Toxoplasma*, *Trichinella*)
 - settlement in organs or tissues of the host where the defense mechanisms are less efficient (e.g., *Fasciola* and *Opisthorchis* in bile ducts)

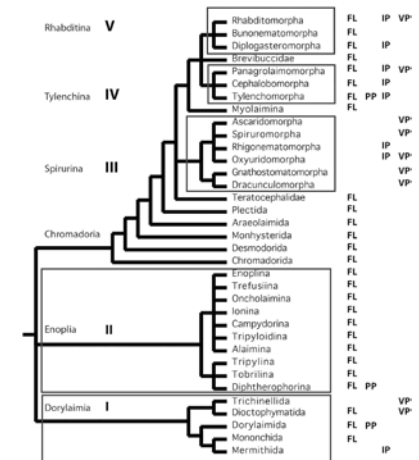


Millions of years have given life to a wonderful dance

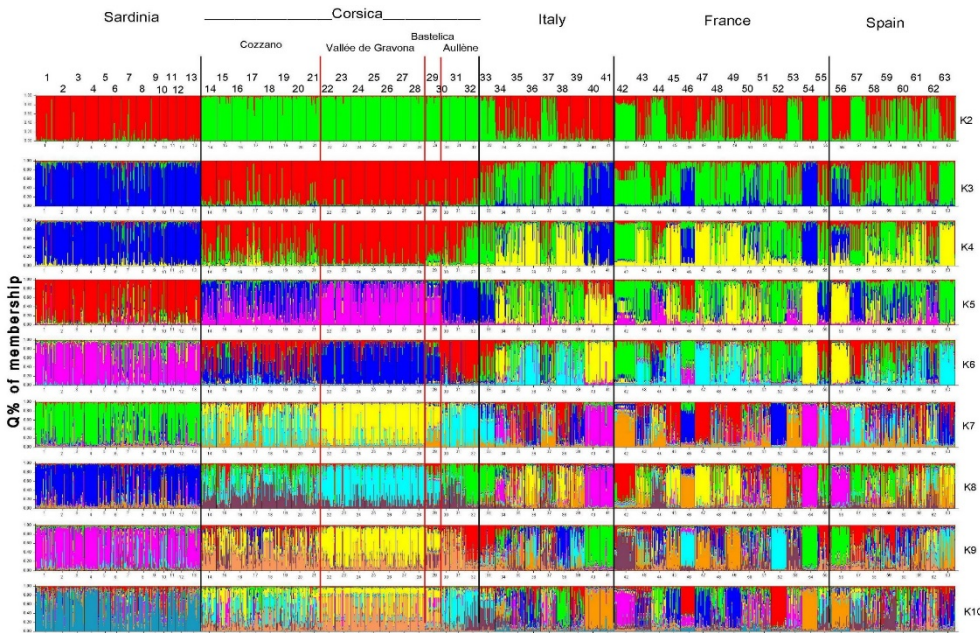
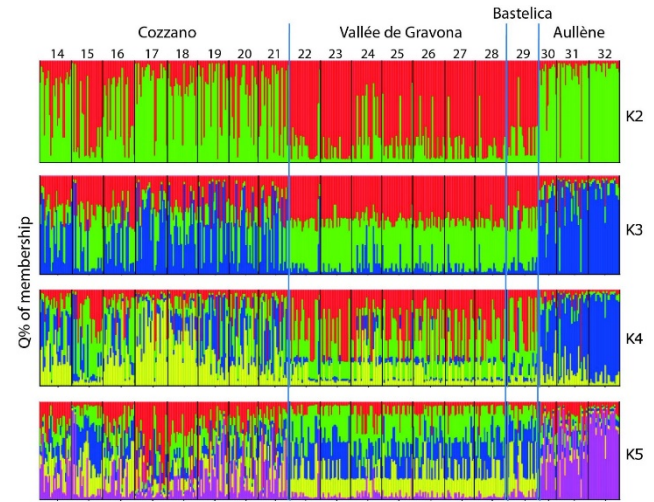


The recent past of FBP research

- Studies of genomes
- Phylogeny of taxa
- Identification of sibling species
- Improvement of serological tests
- Antigen purification
- Investigation on humoral and cell-mediated immune responses against FBP
- Deep investigations on epidemiological patterns

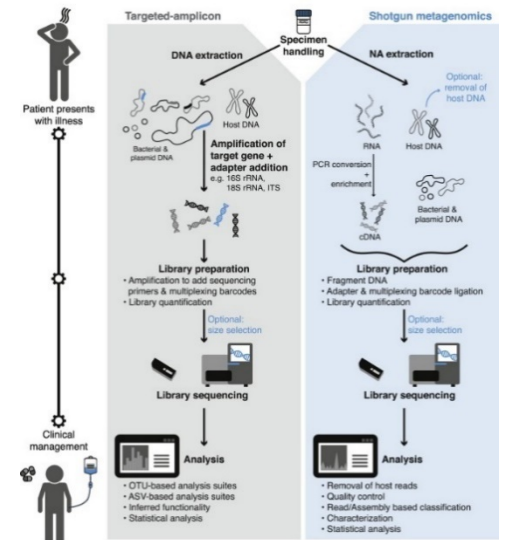
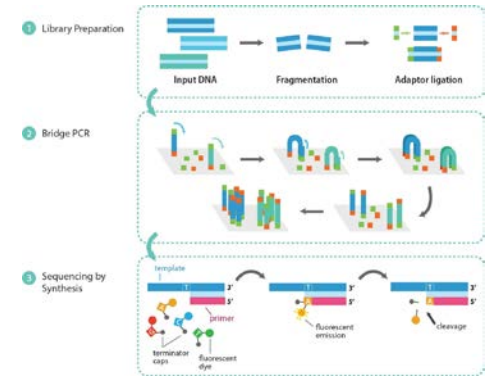


Few years ago, it was inconceivable to trace back *Trichinella* infections from fork to farm



Present research on FBP

- NGS approaches to FBP (e.g., *Cryptosporidium*, *Giardia*, *Cyclospora*, *Trichinella*)
- Metagenomics (e.g., to trace parasites in environmental samples)
- Investigations on the impact of parasites on the human gut microbiome
- Proteomics



What we should keep in mind

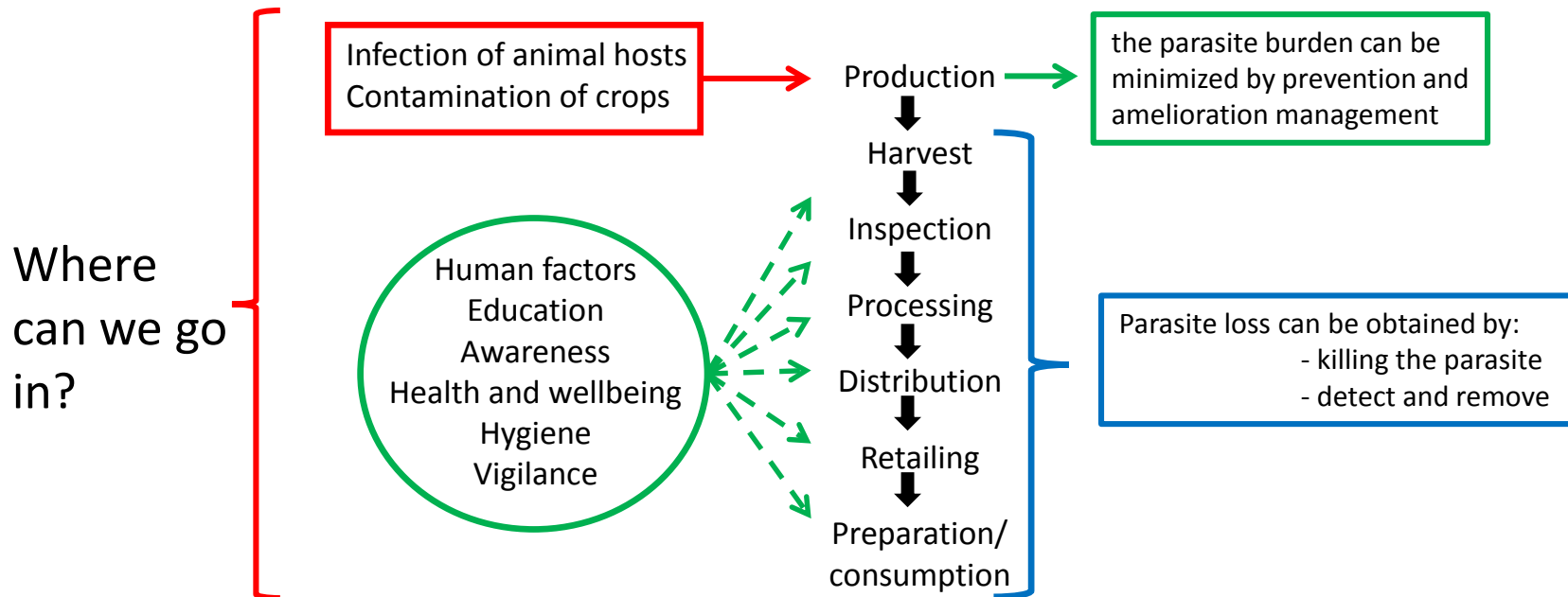


- Most foodborne parasites (FBP) are linked with old and poor farming practices and/or to wildlife
- Poor farming practices are linked with uneducated farmers who, through their incorrect behavior, can favor transmission of e.g. *Echinococcus*, *Toxoplasma* and *Trichinella*
- Uneducated hunters and fishermen can favor transmission of meat- and fish-borne parasites
- Uneducated pet animal owners can favour the spread of *Toxocara* eggs in the environment if they do not properly treat their animals
- The increase of the human population density in megacities results in a high environmental and water contamination with, e.g. *Cryptosporidium* and *Giardia*
- The increased temperature could favour the establishment in Europe of foodborne parasites currently circulating in tropical areas (e.g. *Cyclospora*)



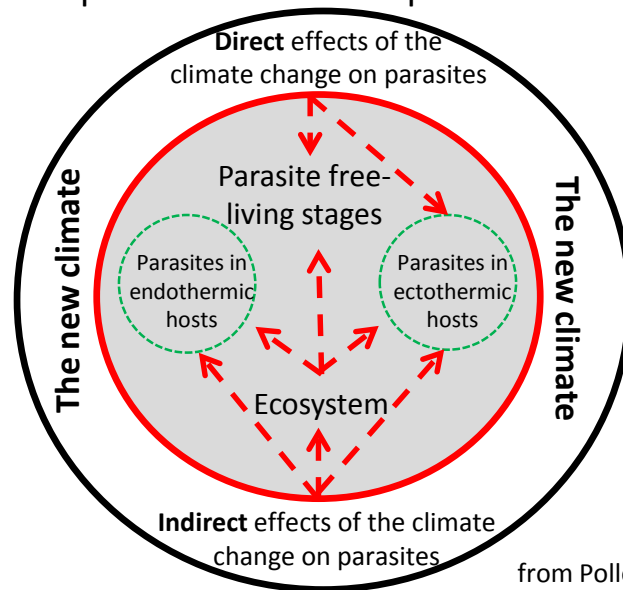
Parasites and the food supply system

- Food passes through various phases of a food supply system (farm to fork)
- Farmers, hunters, fishermen, globalization and climate change can impact on foodborne parasites at each phase of this system



Possible links between climate change, hosts, parasites and ecosystems

- Globalization and climate change:
 - cause epochal migration of human populations
 - cause a reduction of animal species and habitat variability
 - have different impacts on foodborne parasites



from Polley L.R., 2015



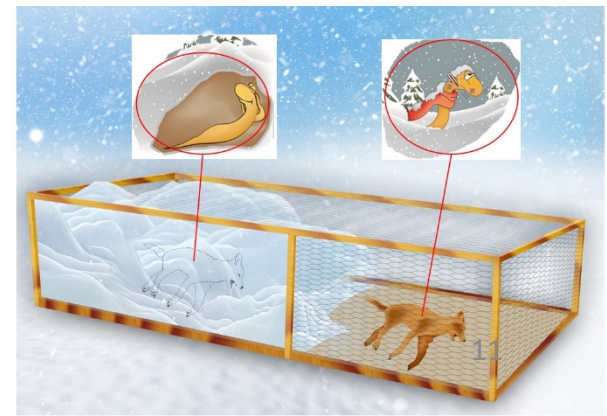
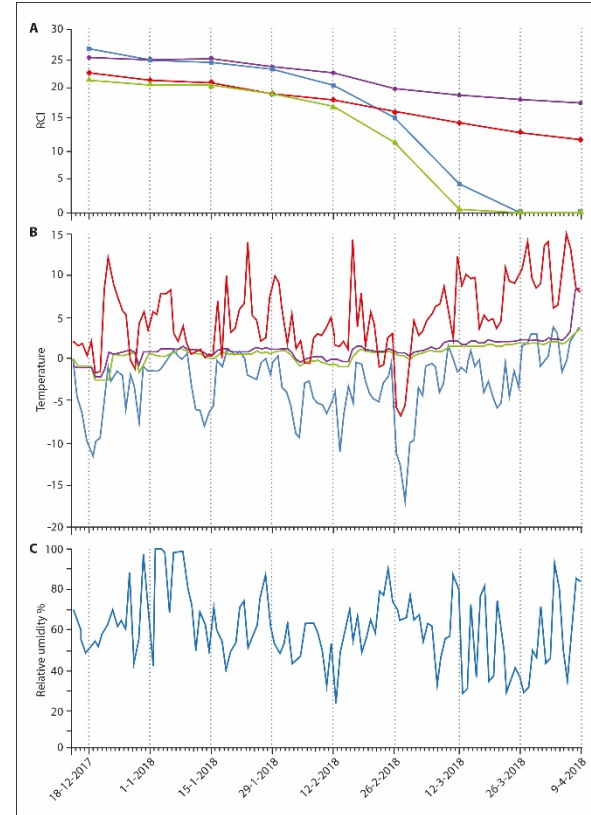
Climate change and foodborne parasites

- A direct influence on parasite cycles:
 - Increasing/decreasing the survival of parasite stages in the environment
 - Increased humidity favors the survival of parasite eggs and cysts/oocysts
 - Increased temperatures accelerate parasite development in the environment and in ectothermic hosts, but shorten the survival of parasite eggs, cysts and oocysts
 - Rainfall intensity increases the spread of eggs, oocysts and cysts by water
 - Increased drought periods reduce the survival of parasite eggs, oocysts and cysts, but increase the eggs, oocysts and cysts concentration in water
 - The ozone depletion reduces the survival and infectivity of parasites in the environment
 - The reduction of good water resources increases the risk of outbreaks due to the consumption of low quality water

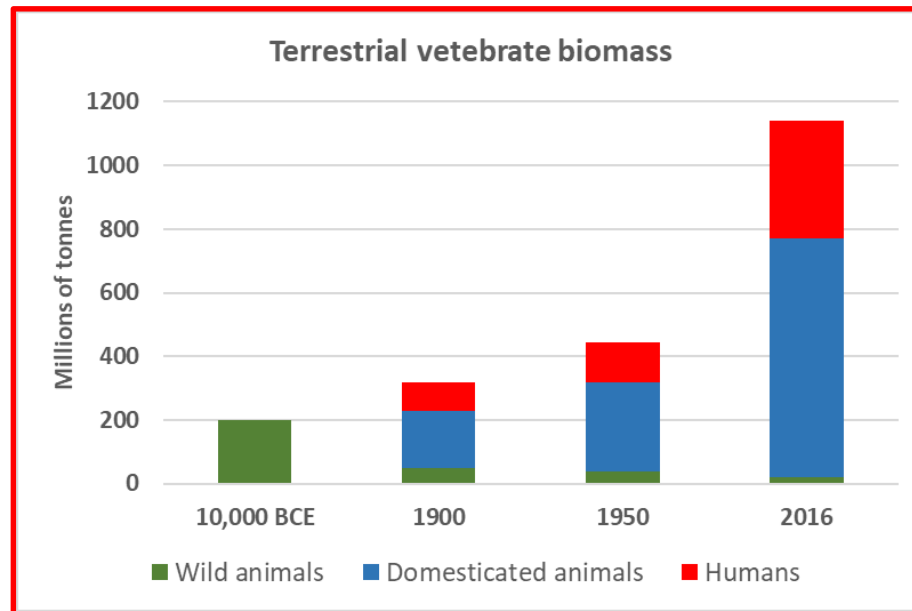


Climate change and foodborne parasites – The *Trichinella* example

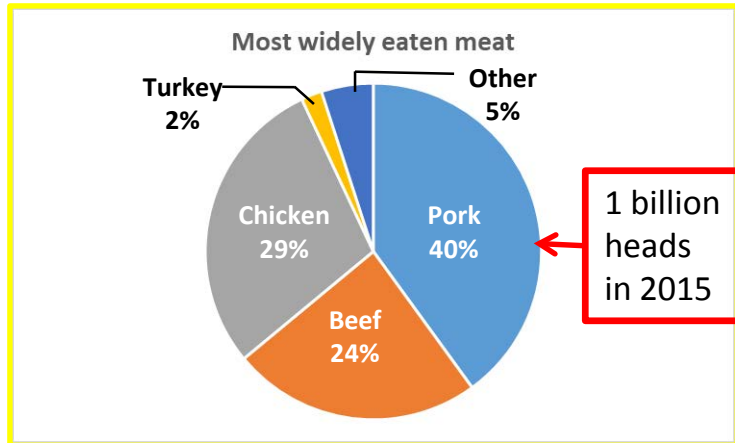
- *Trichinella* infection strongly reduced in red foxes of Alps (from 20%-35% in the fifties to 0.0%-0.01% in the last years)
- At the same time, the snow depth and snow cover in the Alps showed a significant decrease
- We investigated the survival time of *Trichinella britovi* larvae in host carcasses preserved beneath or above the snow in the Alps
- The results showed that *T. britovi* larvae survive longer in carcasses beneath the snow than in those above the snow
- The stability of the environment beneath the snow favors the survival of *T. britovi* larvae in host muscles, increasing the probability of their transmission to other hosts
- On the other hand, the environment above the snow, characterized by sudden temperature variations, causes strong environmental stress for larvae in host carcasses causing their death



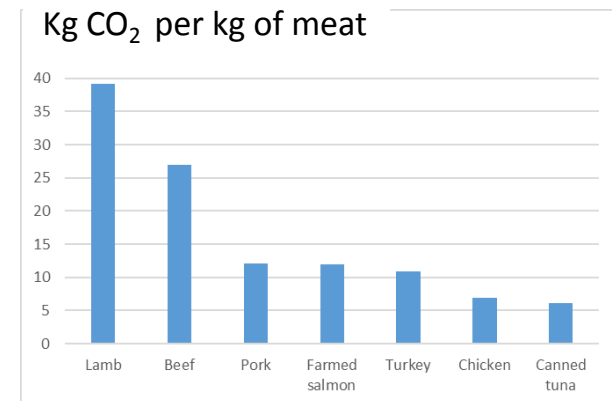
Change of biomasses



The environmental impact of food animals

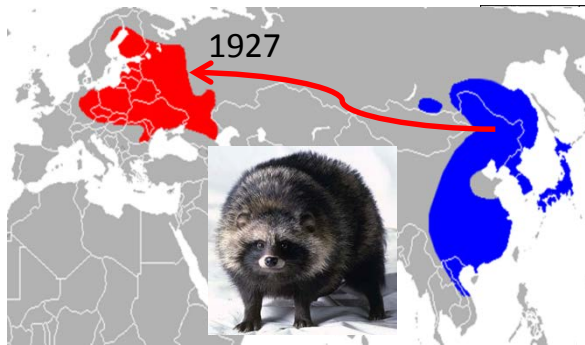


Animal species	Water consumption (L) for 1 kg meat production	The future of meat and fish consumption
Chicken	1,000	↑
Pig	6,000	↑
Cattle	16,000	↓
Fish		↑



Introduction of alien host species

- In the last century, 44 alien mammalian species reached Europe, including several carnivores, such as the American mink, the raccoon, the raccoon dog, and the jackal



Echinococcus multilocularis
Trichinella spp.



Baylisascaris
procyonis



Echinococcus spp.
Trichinella spp.



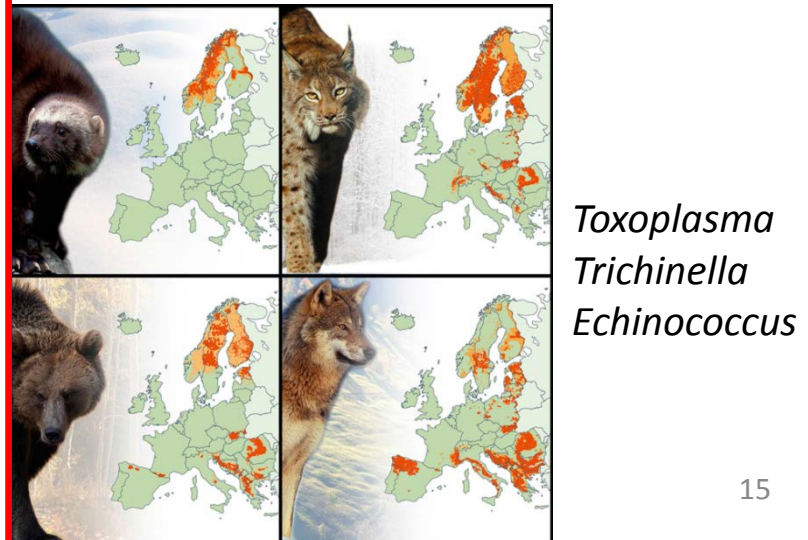
Trichinella spp.

Changes of animal behavior and population growth

- Increase of wild animal populations reservoir host of parasites



Large carnivores are making a comeback in Europe as a consequence of wild herbivores and wild boar population growth



Environmental changes and anthropization

- Increased availability of food resources for wild animals in urban and rural areas
- Increase of urban, residential outskirts, and suburban areas
- Reduction of rural areas and wild lands
- Reduction of the environmental hygiene
- Huge increase of pet animals, which, if no properly reared, can be the source of FBP (e.g., *Toxocara*, *Toxoplasma*)

Toxocara spp. in urban and rural areas

- In the Western countries, the seroprevalence of *Toxocara* infection varies:
 - between 2% and 5% in urban areas
 - 15%–20% in semi-rural zones such as residential outskirts of large cities
 - peaks at 35%–42% in rural areas
- Factors that have been associated with an increased rate include a low socioeconomic level and poor environmental hygiene
- These factors could possibly be exacerbated by warm climates, i.e. those favored by the global warming

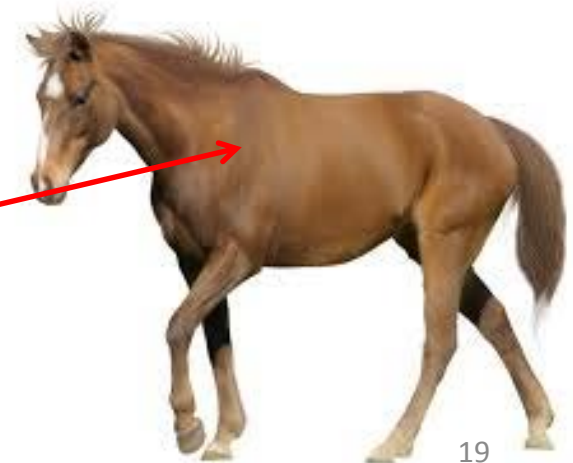
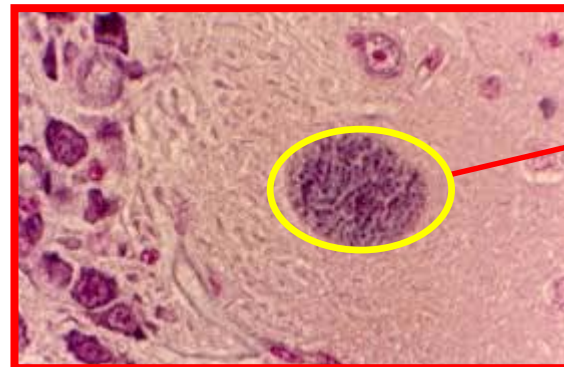
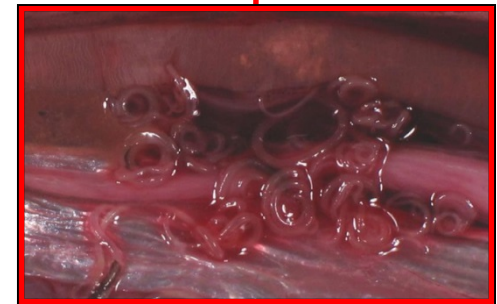
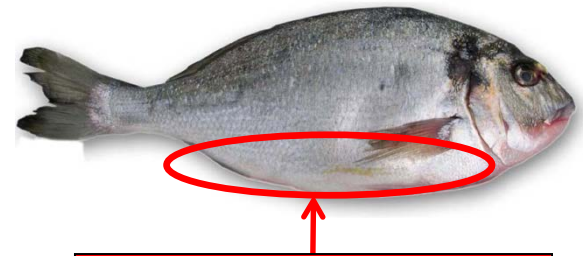
Impact of globalization on meat and fish borne parasites - 1

- Most of meat and freshwater fish borne parasites occur in poor and disadvantaged areas of the world
- Industrial livestock and fish farms are exempted from foodborne zoonotic parasites
- Illegal importation of meat, freshwater fish products, and vegetables can be the source of human outbreaks when introduced by personal baggage:
 - Wild boar meat infected with *Trichinella* introduced from Eastern to Western European countries
 - *Opisthorchis* infected carp brought in Israel from Russia by immigrants



Impact of globalization on meat and fish borne parasites - 2

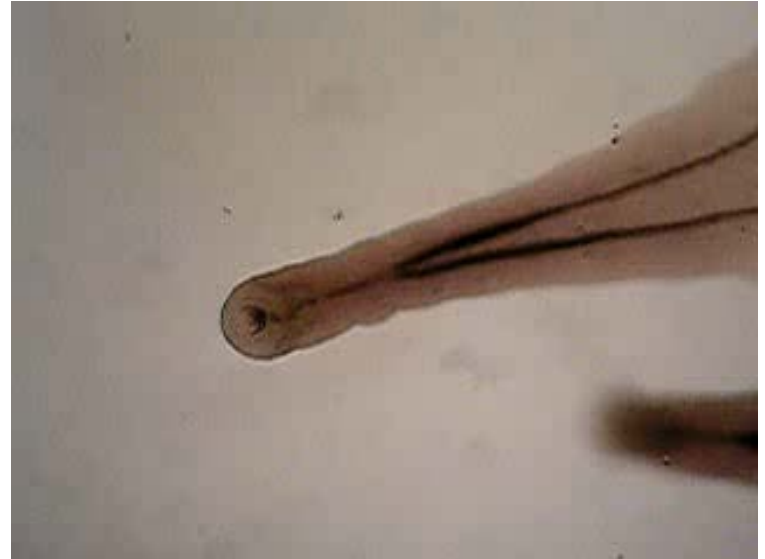
- Trade globalization may result in spreading:
 - Anisakidae worms by wild fish and cephalopods
 - 'atypical' *Toxoplasma gondii* strains by livestock and their meat from south America
 - persons infected by European *Toxoplasma gondii* strains are not protected against 'atypical' strains
 - freezing meat and fish products may reduce the health impact but cannot resolve the problem



Introduction of new food habits

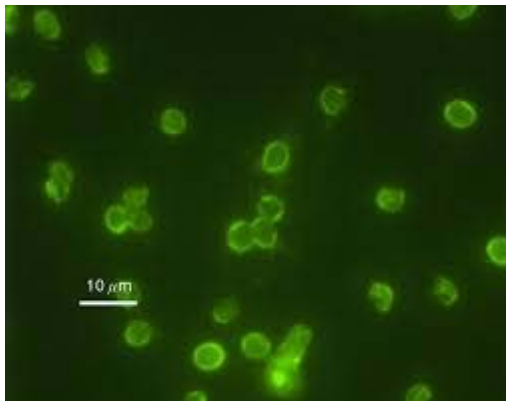
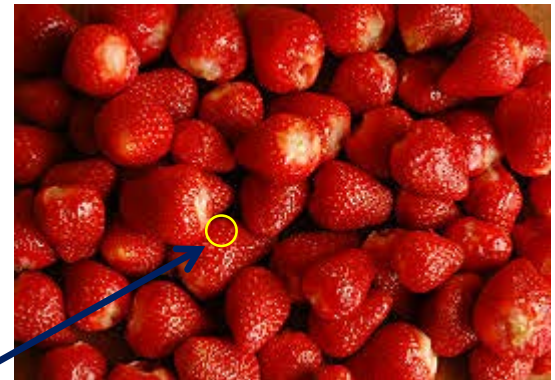
- The *Opisthorchis felineus* example

- Described for the first time in lakes of Central Italy at the end of the 19th century
- No human case were documented up to 2003, when the consumption of raw tench fillets began to be popular
- More than 200 human infections have been described in 9 years (2003-2011)
- Some tourists acquired the infection in Italy and developed the disease when they come back home (Netherlands, Austria)
- Chronic and untreated infections can result in the development of cholangiocarcinoma



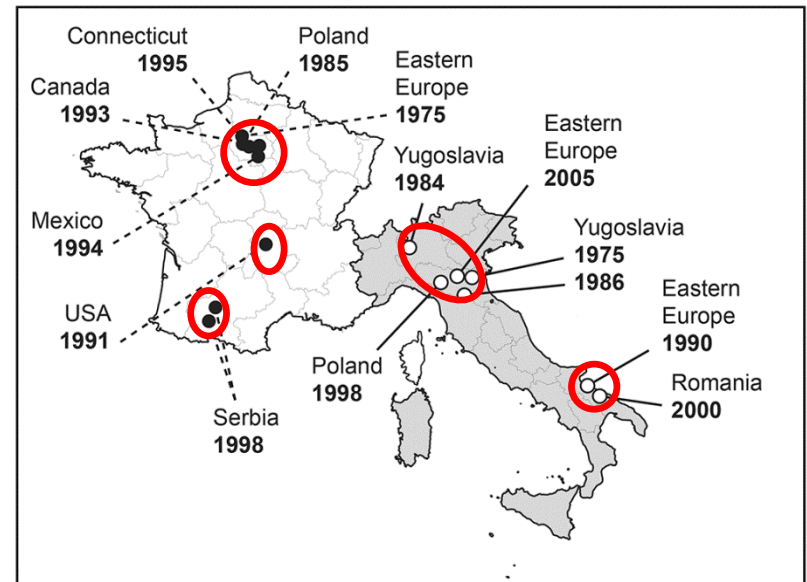
Impact of globalization on the international trade of vegetables and fruits

- Fruits and vegetables can be contaminated by *Cryosporidium*, *Cyclospora* and *Toxoplasma* oocysts, *Giardia* and *Entamoeba* cysts, worm eggs
 - Contaminated fruits and vegetables have been imported from Central to North America
 - In the EU, fruits and vegetables are not tested for these pathogens



Relationship between meat trade globalization and food habits

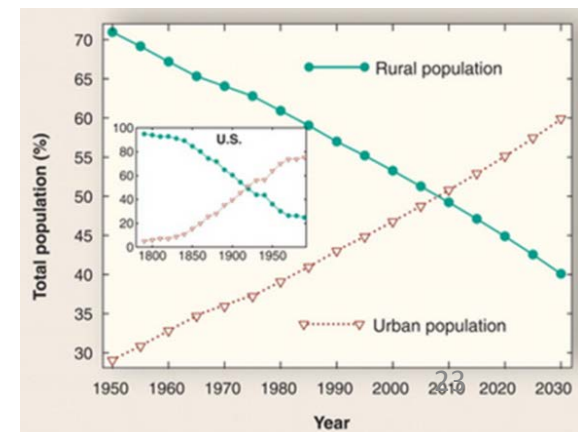
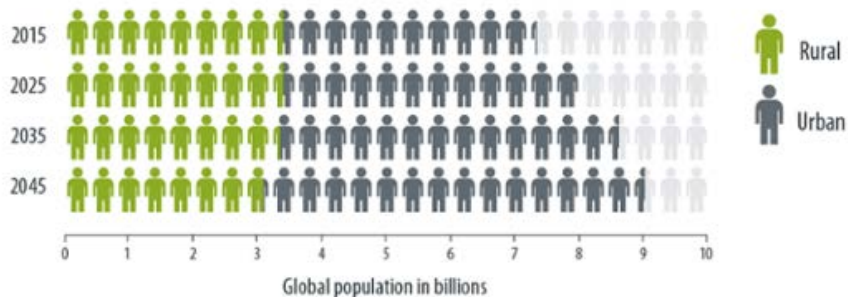
- *Trichinella* spp. imported by horse meat
 - 8 outbreaks (2296 cases) of trichinellosis have been documented in France
 - 7 outbreaks (1038 cases) of trichinellosis have been documented in Italy
 - resulting from the consumption of horsemeat imported from Eastern European countries (Former Yugoslavia, Poland, Serbia, Romania) or from North America (Canada, Mexico, USA)



Urbanization

- At the global level from 2010, people living in urban areas are more than people living in rural areas
 - In urban areas of megalopolises
 - the higher concentration of humans
 - the dissolution of social structure
 - the immigration of people with different cultural practices
 - the lack of sanitation, controlled water supply and sewerage system increase the risk of foodborne protozoa transmission (e.g., *Cryptosporidium*, *Giardia*, *Entamoeba*, *Toxoplasma*)
 - People with chronic foodborne parasite infections (e.g. echinococcosis, opisthorchiasis) acquired when they lived in rural areas years before, are not properly diagnosed and treated

A growing population living in the urban environment



Carnivore populations from wild to urban areas

Wild populations are strongly limited by environmental factors:

- increased urban areas
- climate change

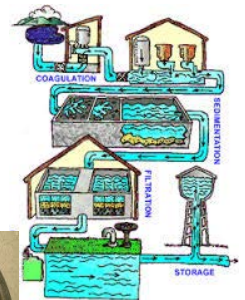
The urban populations are increasing:

- abundant feed resources
- lack of hunting pressure
- lack of large predators



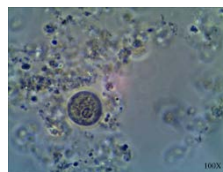
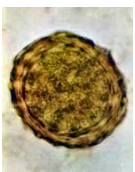
Control of foodborne parasites in the globalization and climate change era

- International food and health organizations need to provide consolidated safety guidelines for the most important foodborne parasites
- Integration of veterinary and public health efforts, i.e. the one health concept
- Training of physicians and veterinarians
- Education of both native and immigrant populations:
 - Consumers
 - Farmers
 - Hunters
 - Fishermen
- Information of policy makers
- Appropriate disposal of wastes of animal origin
- Control of drinking water resources
- Improvement of terrestrial and sea animal husbandry



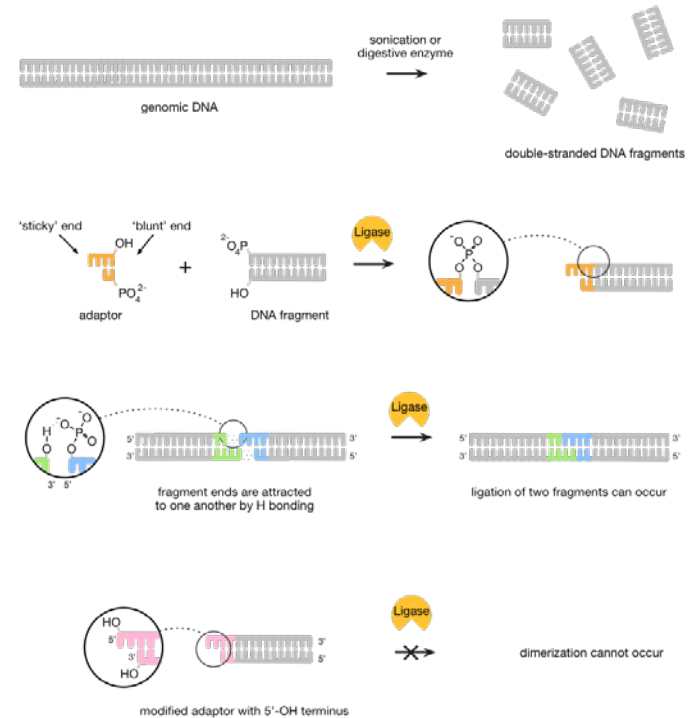
Foodborne parasites and immigrants

- Intestinal parasite burden (e.g., *Ascaris*, *Trichuris*, *Entamoeba*, *Cyclospora*, *Cryptosporidium*, *Giardia*, *Taenia*) reduces in few months due to the lack of reinfection, however:
 - Most European physicians are not aware of the epidemiology, clinical patterns, diagnosis and treatment of these infections
 - There is a strong reduction of the availability of anti-parasitic drugs on the EU market
 - No new anti-parasite drugs are being developed
- Cultural practices of immigrants can favor the transmission of foodborne parasites
 - *Taenia saginata* (field defecation of shepherds and farmers)
 - *Echinococcus granulosus* (dogs feed with offal and scraps of animals illegally slaughtered at the farm)

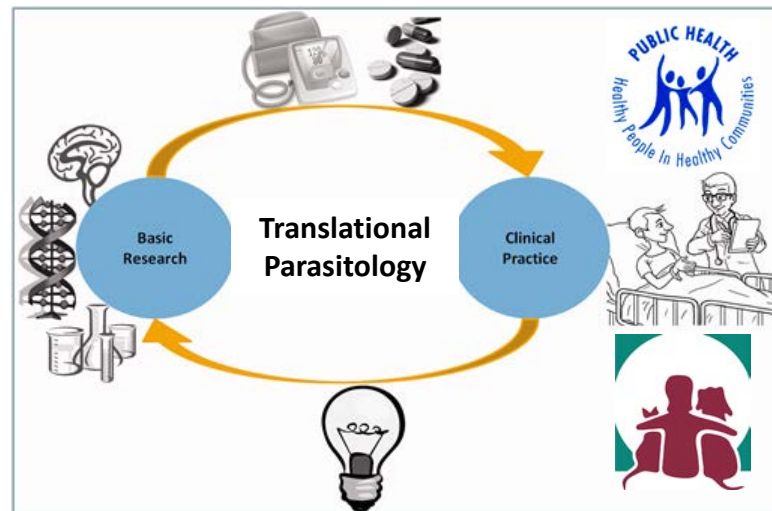


The present

- Technologies strongly bias the research investigation, but not always research succeed to answer the questions
- We often use very powerful investigative tools, but we lack original ideas



Translational parasitology



Translational medicine

- 17 year innovation adoption curve from discovery into accepted standards of practice
- Lack of innovation adoption planning in the discovery process
- Even if an innovation is accepted as a standard of practice, patients have a 50/50 chance of receiving appropriate care



What we need in the field of food-borne parasites

- Basic research
 - NGS of FBP
- New drugs
 - No effective drug available for cryptosporidiosis
 - Anti-*Toxoplasma* drugs are not active against tissue cysts
 - The drugs used today for the treatment of alveolar and cystic echinococcosis are only parasitostatic and not parasitocidal
- New diagnostic tools
 - to identify animals with active tissue cysts of *Toxoplasma gondii*
 - to unequivocally diagnose cystic and alveolar echinococcosis
 - to trace FBP from fork to farm
- New educational tools
 - to train farmers, hunters, fishermen, pet owners, consumers to veterinary and public health in the field of FBPs and their risks



15-20 years



- In the future, young parasitologists when will plan their investigations, will have to keep in mind these issues to prioritize their studies
- and at the end of the work, when the manuscript must be published there is the review process!!!

